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Freshwater Inflow Requirements of a Texas Estuary

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Abstract

The objective of this study is to estimate the amount and scheduling of freshwater inflows required to maintain fishery productivity, especially shrimp, in Matagorda Bay, Texas. To estimate the levels of river flows required, we principally used correlation and regression analyses of commercial shrimp catches versus gaged river flows.

To maintain the 709,792 kg annual shrimp harvest, we recommend an annual gaged inflow of 1,048,050,000 m^3 from the Lavaca-Navidad River and 2,197,206,000 m^3 from the Colorado River, which total 102% of the mean annual flows, 1960-82. For the months of January, February, May, July, August, November, and December, which showed no significant ($p<0.10$) correlations between their flows and shrimp harvests, we recommend the monthly mean flows from each river. Significant correlations were found between March, April, June, September, and October river flows and shrimp harvests; recommended flows were above their monthly means for all but April.

Introduction

Texas has seven major estuarine systems, all of which are greatly influenced by the amount and timing of freshwater inflow. It has long been recognized that freshwater distribution and abundance has a tremendous influence on the economic prosperity of a region. The "Texas Basins Project", prepared by the U.S. Bureau of Reclamation in 1965, was the first long range comprehensive plan and it remains at the core of the state's water development plans today. Through a series of reservoirs and aqueducts, water could be moved from the water-rich east Texas watersheds to the water-poor Corpus Christi and lower Rio Grande valley areas. This plan was updated most recently in 1984 by the Texas Department of Water Resources (TDWR 1984). This water transfer plan could reduce productivity in some bay systems.

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This study is restricted to the Matagorda Bay System (Fig. 1), because there are several imminent water development proposals that could modify the freshwater inflows of that bay. The objective of this report is to make an estimate of the amount and scheduling of freshwater inflows required to maintain and enhance fishery productivity in the Matagorda Bay System. Although the shrimp fishery is not the only valuable fishery in the Matagorda Bay System, it is a major one for which data have been collected over many years, and is the primary focus of this report.

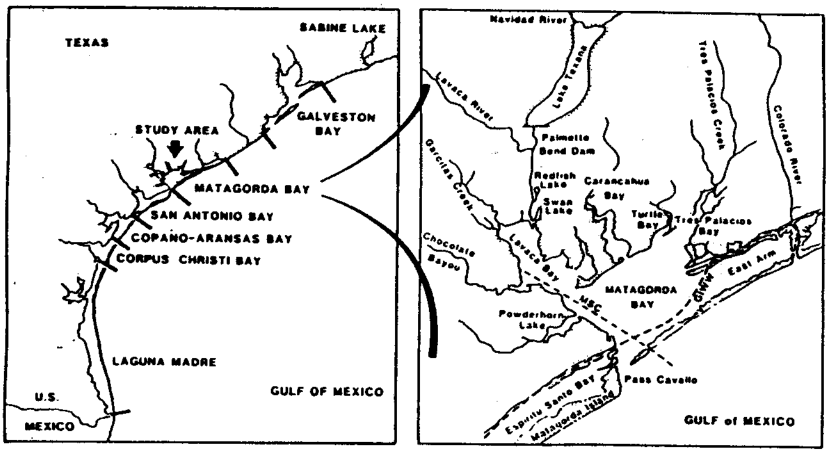

Figure 1. The Matagorda Bay System and its tributaries.

Description of the Matagorda Bay System

The Matagorda Bay System is a shallow (average depth 2m) estuary on the central Texas coast. The study area covers about 993 km^2 (Diener 1975) with approximately 140 km^2 of salt and brackish marsh in the system. Three rivers and several creeks contribute freshwater inflow to the Matagorda Bay System (Fig. 1). The largest river is the Colorado River with 75,110 km^2 drainage basin, which enters the estuary thru the Gulf Intracoastal Waterway, Culver Cut, and Tiger Island Cut, but a large percentage of the flow empties directly into the Gulf of Mexico. The Lavaca and the Navidad Rivers with a combined drainage basin of 5983 km^2, join about five miles before the Lavaca River enters Lavaca Bay. Local runoff enters the bay system from two coastal drainage basins having a total area of 4740 km^2.

The Matagorda Bay System is very dynamic and has been subjected to a series of increasingly frequent natural and man-made perturbations. In 1929 an enormous log jam on the Colorado River was broken by a combination of dredging, dynamiting, and flooding. The trapped sediment was released and the present delta rapidly began to form. Dredging to relieve upstream flooding channelized the delta formation and opened the channel through Matagorda Peninsula, allowing the Colorado River to discharge directly into the Gulf of Mexico (Sheffield and Walton 1981). There was a great reduction in the amount of both freshwater and sediment entering Matagorda Bay. In addition, a series of upstream reservoirs and increased diversions have reduced the discharge at the mouth of the Colorado River.

Currently under construction is the navigation portion of the Mouth of the Colorado River Project. The existing channel is to be enlarged upstream to the town of Matagorda. Tiger Island Cut will be filled with dredged spoil. A second phase of this project, not yet under construction, will divert the entire Colorado River flow into Matagorda Bay.

The Lavaca-Navidad drainage has also been affected by reservoir construction. In May 1980, Palmetto Bend Dam on the lower Navidad River was closed, forming Lake Texana. Since it is very close to the bay, its impacts on freshwater inflow are significant, potentially reducing inflow by 113,436,000 m^3 annually and reducing sediment input to the Lavaca delta by 49% (U.S. Bureau of Reclamation 1974).

Materials and Methods

Gaged river flow data were obtained from publications by the Texas Department of Water Resources (TDWR) in cooperation with the U.S. Geological Survey. Monthly flow volumes and flow rates were obtained for the Lavaca, Navidad, and Colorado Rivers from 1960 through 1982. The Colorado River empties into both Matagorda Bay and into the Gulf of Mexico. The flows calculated to enter Matagorda Bay were based on gaged flows recorded near Bay City subjected to adjustment procedures based on Figures 5-26 and 5-27 of LP-106 (TDWR 1980). The monthly volumes of water released each month from Lake Texana since flow curtailment was initiated in May 1980 were provided by the Bureau of Reclamation (pers. commun. Mr. John Goar and Mr. Eugene Hinds).

Annual and monthly gaged flow volumes from 1960 thru 1982 for the Colorado River and for the Lavaca-Navidad River fluctuated widely. The minimum annual flow for the Colorado River was 424,152,000 m^3, the maximum was 4.7 billion m^3, with a 23-year mean of 2.1 billion m^3. The Lavaca-Navidad River had a minimum annual flow of 165,098,700 m^3, and a maximum of 2.5 billion m^3 with a mean of one billion m^3. Minimum summer monthly flows have been as low as 1,200,000 m^3 in both rivers. Highest monthly flows are in June for both rivers; 1.2 billion m^3 in the Colorado and 1.0 billion m^3 in the Lavaca-Navidad.

Catch data for the shrimp fishery in the Matagorda Bay System were obtained from the Texas Parks and Wildlife Department (TPWD) and National Marine Fisheries Service (NMFS) cooperative publications (U.S. Department of Commerce and Texas Parks and Wildlife Department, 1961-1984). Shrimp landings used herein are in kilograms of shrimp tails.

The mean annual catch for white shrimp is 523,000 kg and for brown shrimp it is 186,792 kg. The first portion of the annual fishery begins in May and continues thru July (Fig. 2). About 94% of the annual brown shrimp catch is made during this period. The second portion of the annual fishery begins in August and continues thru December. This five month period accounts for 93% of the annual white shrimp catch in the bay.

Our anaylsis of the freshwater inflow to maintain or enhance the shrimp fishery involved the correlation and regression of various flows with commercial harvest data. Our anaylsis of the commercial harvest data for each of the two major shrimp species used the following steps:

1. Correlation of annual flow of each major river (Lavaca-Navidad and Colorado) versus annual catches.
2. Correlation of seasonal flows of each major river versus annual catches.
3. Correlation of monthly flows of each major river versus annual catches.
4. Regression of monthly flows of each major river and of their combined flows versus residual catches.
5. Derivation of several sets of monthly flows from the regression anaylses (or from mean flows for 1960-1982 in cases where there was no statistically significant regression relationship).
6. Derivation of required number, scheduling, and size of floods.
7. Reduction of several sets of monthly flow volumes from #5 and the flooding requirements from #6 to one flow value for each month.

Residual catch is that portion of the annual catch that occurred during and after the flow month under anaylsis. In an effort to select a period with a fairly uniform effort, we have restricted our analyses for brown shrimp to the 1961 through 1978 catches and for white shrimp to the 1961 through 1976 catches.

Both linear and quadratic regression equations were used. Using the quadratic regression equations, the relationship between flow and harvest sometimes holds until flow surpasses a certain level, a threshold. This allows us to select the peak of the curve as the optimum flow, above which increased flows have a negative effect on harvest. We refer to this procedure as "thresholding" and view it as a powerful tool.

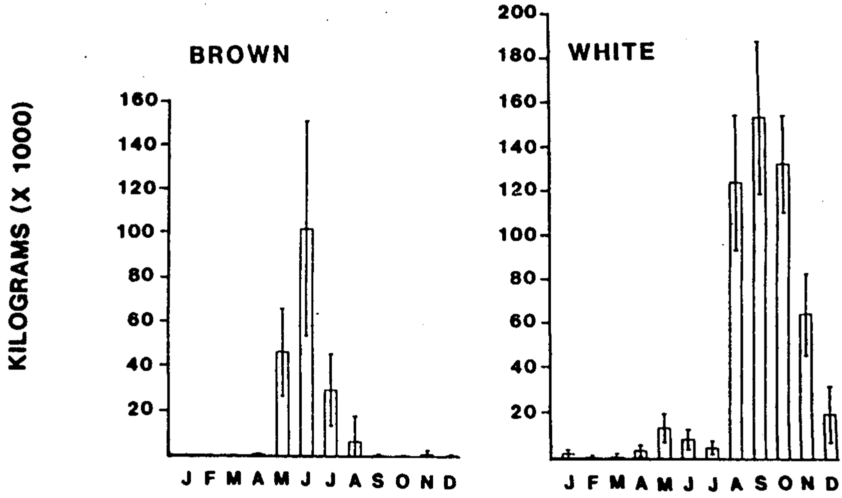

Figure 2. Means and 95% confidence limits for monthly commercial catches of brown and white shrimp in the Matagorda Bay System, 1961-82. Values are kilograms of shrimp tails.

We used procedures (Table 1) which emphasize values derived from significant equations and the use of thresholding to reduce a list of several possible flow values to the one best set of values. Where the analysis has not provided reliable guidance in flow requirements, we have selected the mean historical flow for that month.

Results

Annual catches of both brown and white shrimp showed poor correlations with annual inflows and with annual inflows of the previous year. Only the correlation using 1962-76 white shrimp catches versus the lagged and adjusted Colorado River flows was significant ($r = -0.49$, $p<0.10$). This negative correlation signifies that if there was a large inflow from the Colorado during the previous year, there would tend to be a lower catch during the current year.

Seasonal flows also correlated poorly with annual catches of brown and white shrimp. There were no significant correlations between seasonal river flows of either river and annual catches of brown shrimp for the period 1961-1978. For annual white shrimp catches (1961-76), only spring (April-June) Lavaca-Navidad River flows showed a significant correlation ($r = 0.58$, $p<0.05$).

Table 1. Procedures for flow selections using the linear and quadratic regression equations.

Step

1. If both equations are significant ($p<0.10$) and select the same flow value, use that value.

2. If both equations are significant and the quadratic equation selects two values for the mean harvest level, use the mean harvest flow value selected by the linear equation.

3. For the remaining cases where both equations are significant but elect different flow values, use the average of the two values.

4. If the linear equation is significant and the quadratic equation is not, use the flow values selected by the linear equation.

5. If the quadratic equation is significant and the linear equation is not, use the flow values selected by the quadratic equation, except in cases where the quadratic equation selects two flow values for the mean harvest level.

6. Use thresholding, where possible, for the determination of the maximum harvest flow value, if the r^2 of the quadratic equation is at least 0.10 and the linear equation is not significant.

7. For any flow values that remain undetermined, use the mean historical flow for the period of analysis.

Analyses using monthly river flows versus annual white shrimp catches yielded several significant correlations. Positive correlations were found for white shrimp annual catches and March ($r = 0.56$, $p<0.05$), April ($r = 0.49$, $p<0.05$) and June ($r = 0.71$, $p<0.01$) monthly Lavaca-Navidad River flows. October monthly flows provided the only significant correlation for the Colorado River and annual white shrimp catches ($r = 0.44$, $p<0.10$). No significant correlations were found between monthly river flow volumes and annual brown shrimp catches. The results from these correlation analyses suggest the use of monthly increments of inflow for establishing inflow-to-harvest relationships.

Regression tests were performed first for white shrimp residual catches versus monthly flows of the rivers individually and then combined. Both linear and quadratic regressions were used for each case. The same tests were also made using brown shrimp catches.

Significant regressions between residual white shrimp harvests and monthly flows of the Lavaca-Navidad River were found for March, April, June, September, and October (Table 2). Significant regressions between residual white shrimp harvests and adjusted monthly flows of the Colorado River were found only for April and October (Table 2). Similar tests but for the combined river flows yielded significant regressions for March, April, June, and October. The monthly mean flows were recommended for maintaining the mean harvest level of white shrimp for the months without significant regressions. Monthly flows for enhancing the white shrimp harvest used thresholding for September and November flows of the Lavaca-Navidad River, and for February, March, July, and September adjusted flows of the Colorado River.

Regression analyses for brown shrimp were similar to those for white shrimp, except only January thru August and the previous December were examined. The later months were dropped because there is little brown shrimp catch in the bay after August, and there is very little expectation of carryover to the next year's catch. The only significant regression found was for adjusted Colorado River flows in June. Consequently, the calculated monthly flow volumes for maintaining the mean catch levels were based on mean monthly flow volumes. Thresholding was useful in some months for determining the calculated flows for achieving the maximum brown shrimp commercial harvest.

To establish unified flow recommendations for the Lavaca-Navidad River and for the Colorado River, the flows calculated for white and brown shrimp were combined by choosing the flow that explained the greatest amount of variability in the shrimp harvest, i.e., that flow selected using the lowest step in Table 1.

For maintaining the mean fisheries level, the historical mean flows for most months were used for both rivers. For the Lavaca-Navidad River these included the means for January, February, May, July, August, September, November, and December (Table 3). The mean flows of these months plus those for March and June were used for the Colorado River. Significant regressions ($p<0.10$) for March, June, and October flows of the Lavaca-Navidad River and for October flows of the Colorado River show that flows above the monthly means would be needed, while April flows below the mean would be appropriate for both rivers. The sum of the monthly recommended flows total 102% of the mean annual flow for the 23-year period-1960 thru 1982.

The recommended flows for maximum shrimp production (Table 3) are at or near the historical highs for several months. For Lavaca-Navidad River these are March, April, June, and October, and for the Colorado River they are April and October. These unusually high monthly flow recommendations were derived from significant linear and quadratic regression equations relating white shrimp residual harvest to March, April, June, and October river flows and relating brown shrimp residual harvests to June river flows.

Contained within the total monthly flow requirements are allowances for flood events. Floods in delta marshes have three functions: 1) to provide sediments that initially build the marshes and later maintain its elevation; 2) provide the medium for nutrient

Table 2. Significant ($p<0.10$) regression equations for monthly river flows (x) as they explain changes in residual white shrimp commercial catches (y) in the Matagorda Bay System, 1961-76.

		r^2	Significance $p<$
	Lavaca-Navidad River		
March	$Y = 847 + 4.35x$	.32	.05
	$Y = 908 - 0.10x + 0.028x^2$	.35	.10
April	$Y = 880 + 1.93x$	.25	.05
	$Y = 1020 - 3.41x + 0.015x^2$	.44	.05
June	$Y = 799 + 1.22$	.47	.01
	$Y = 848 + 0.33x + 0.001x^2$	.49	.05
September	$Y = 741 - 0.55x$	.05	n.s.[a]
	$Y = 577 + 5.23x - 0.016x^2$	.34	.10
October	$Y = 292 + 2.12x$	.44	.01
	$Y = 365 - 1.75x + 0.018x^2$	.63	.01
	Colorado River		
April	$Y = 858 + 1.32x$	.11	n.s.
	$Y = 980 - 0.48x + 0.001x^2$	.39	.05
October	$Y = 292 + 1.04x$	.22	.10
	$Y = 534 - 4.02x + 0.014x^2$	.59	.01

[a]not significant, $p> 0.10$

import and export to and from the marsh; and 3) provide the medium for import and export of detritus to and from the marsh. For the Colorado River, we have identified one large flood per year that should accomplish these flooding objectives (Table 4). Smaller floods would flush the post-diversion delta marshes and also provide sediment. Historical patterns were recommended, because these were the basis for post-diversion delta growth predictions (Coastal Environments, Inc. 1980). Before Palmetto Bend Dam was closed, the Lavaca delta was growing (McGowen et al. 1976). This indicates that the historic frequency and timing of floods was adequate for the continued viability of the delta nursery habitat (Table 4).

Table 3. Recommended river flow volumes by month, including a comparison with flows recommended by the Texas Department of Water Resources (1984). Alternatives listed by TDWR are: II = Maintenance of Fisheries Harvest, III Shellfish Harvest Enhancement. Values are millions of cubic meters.

A. Maintaining mean shrimp harvest

	Lavaca-Navidad River		Colorado River	
	This study	TDWR Alt. II	This study	TDWR Alt. II
January	78	27	182	109
February	73	33	197	122
March	62	21	160	94
April	76	84	176	164
May	157	143	326	232
June	192	121	306	197
July	37	22	136	65
August	27	43	62	60
September	143	120	160	182
October	96	96	147	113
November	54	22	192	478
December	53	22	53	397
Totals:	1048	753[a]	2197	2217[a]

This study 3245 million m^3 = 102% of mean flow, 1960-82

TDWR 1984 2970 million m^3

B. Maximizing shrimp harvest

	Lavaca-Navidad River		Colorado River	
	This study	TDWR Alt. III	This study	TDWR Alt. III
January	111	27	220	109
February	122	33	242	122
March	212	21	243	94
April	471	14	438	125
May	157	206	326	173
June	1047	143	412	129
July	37	20	160	200
August	27	12	62	136
September	197	30	289	182
October	292	22	540	113
November	74	22	192	473
December	53	22	153	401
	b		b	

[a]Rounding of monthly values make this total slightly different than the sum of the column.

[b]We do not recommend all these high flows in the same year. These are presented to show the potential of increased flows in an individual month.

Table 4. Flooding recommendations.

Minimum Average Daily Flow (m^3/sec)	Frequency	Timing[1]
	Lavaca-Navidad River	
255	2/yr	Mar-June
255	1/yr	Sept-Oct
255	1/yr	Nov-Feb
990	1/2 - 3 yrs	Apr-June, Sept Oct
	Colorado River	
283	2/yr	Mar-June
283	1/yr	Sept-Oct
283	1/yr	Nov-Feb
934	1/yr	Apr-June or Sept

[1]Emphasis was placed on recommending floods during the Critical Flow Months - see text.

Discussion

Spring and early fall flows appear to exert the most influence on shrimp harvest levels. Significant correlations and regressions occur for flows of five months: March, April, June, September, and October (Critical Flow Months). Although we found no significant relationships between shrimp catches and river flows for other months, we feel that the amount of freshwater inflow is still important. Other factors affecting shrimp production could be obscuring the relationships. For the spring period, May is conspicuous in its lack of significant correlations. The data show that both April and June flows are very important, but May flows consistently show a very poor relationship to catch. Small floods on both the Lavaca-Navidad and Colorado Rivers were more frequent in May than in either April or June and could be an explanation for this.

The high flows during spring months would appear to set up the environment - the marshes and bays - with nutrients, detritus, and food organisms for the incoming new-year-class postlarval and juvenile shrimp. The high October flows would appear to act more as a flushing mechanism to push the new-year-class subadult shrimp out of the nursery areas and into the main secondary bays and into Matagorda Bay itself.

The Texas Department of Water Resource (1980) made a detailed study of the freshwater needs of Matagorda Bay, which included three levels of flow recommendations: I. Subsistence, II. Maintenance of Fisheries Harvest, and III. Shellfish Harvest Enhancement. In 1984

TDWR produced a fourth level of flow, Biotic Species Viability. This was defined as a short-term freshwater inflow needs category (TDWR 1984), but it appears to have gained full stature, equivalent to the previous three alternatives.

TDWR's goal for Altenative II was to find the minimal flow that would maintain the average commercial finfish and shellfish harvest, including red drum, spotted seatrout, shrimp, blue crabs, and oysters. Our study concentrated on shrimp and their requirements as representative of estuarine organisms and very important to characterizing an estuary. A comparison of Alternative II flows and our flows to maintain the historical mean harvest of shrimp shows that the total annual recommended flows differ by only 274,959,000 m^3 (Table 3). In order to minimize flows, TDWR concentrated 75% (563,481,000 m^3) of the Lavaca-Navidad River annual flow in the months of April, May, June, September, and October. Except for the exchange of May for March, these are the months we identified as Critical Flow Months. So we agree with their approach that if flow is to be minimized, it should be concentrated in the Critical Flow Months and May to maximize the benefit to the commercial shrimp fishery. Of our recommended flow 63% (664,587,000 m^3) was in those same five months, but because our total flow was larger the flow in those five months was also larger.

Our total flow recommendation for the Lavaca-Navidad River is larger, in part, because the average flows used by TDWR are different from ours. Their period of record is 1941-76, and has an average annual discharge of 757,062,000 m^3. The 1960-82 period we use has an average annual Lavaca-Navidad River discharge of 980,235,000 m^3. Our period corresponds to the span of reliable shrimp harvests records, whereas TDWR's flow period includes many years not used in their harvest data anaylsis.

Our flow recommendations for the Colorado River are very similar to TDWR's in terms of the annual total for Alternative II (Table 3), but the monthly distribution of flows is very different. Our recommendation retains a pattern similar to the Lavaca-Navidad River, with 51% of the flow in April, May, June, September, and October. TDWR has only 40% of the flow in those months, but has 39% of the annual flow in November and December compared with our 16%. Their Estuarine Linear Programming Model calculated that these flows are necessary to achieve average harvests of oysters and blue crabs, species that we did not consider. TDWR did not present any details of their Estuarine Linear Programming Model, so we were not able to judge its accuracy. However, for the period 1960-82 TDWR's recommended November flow was met or exceeded only three times, the December flow only once, and the combined November-December flow only once. These flows are very high and do not seem appropriate. In fact, our regression anaylses show a negative relationship for white shrimp harvest versus adjusted Colordo River December flows, and for white shrimp harvest versus Lavaca-Navidad-Colorado combined December flows.

None of our recommended flows for maximizing the shrimp harvest is above the respective month's historical maximum. Data have not been found that enable us to predict the effect on shrimp harvests if two or more months of our recommended high flows were to occur sequentially or even in the same year. It is not necessary, nor would we recommend, that all of these elevated flows occur during a single year to achieve a harvest level above the mean or at a maximum. These flows are presented to show the potential harvest effects of increased flows in an individual month.

TDWR's Alternative III, Shellfish Harvest Enhancement, seems to be equivalent to our flows for maximum shrimp production. However, TDWR constrained their model from exceeding historical average flows (1941-76). This prevented them from exploring the full potential of high flows. On the Lavaca-Navidad River they increased spring flows at the expense of fall flows. Operating within their constraints, we agree with this change, because we also feel that spring flows are more important than fall. For the Colorado River, TDWR decreased spring flows, increased summer flows, and retained their extremely high November and December flows. The summer flows were increased because TDWR's salinity model indicated a need for reduced salinities in the east arm of Matagorda Bay in July and August to enhance shellfish habitat conditions. The salinity model was not displayed for examination, but this is a potentially critical time for juvenile shrimp and summer salinity conditions were an aspect that we were not able to thoroughly investigate. Oyster habitat considerations would also dictate higher summer flows. With regard to the reduction in spring flows, our data show that reduction, not enhancement, would occur in shrimp harvest.

Matagorda Bay has two major deltas, the Lavaca and the Colorado. Since 49% of the Lavaca delta sediment supply is stopped by Palmetto Bend Dam (U.S. Bureau Reclamation 1974), the recommended floods will probably not be adequate to maintain the size and health of the delta indefinitely, unless Navidad River sediment-carrying flows are diverted around Lake Texana. Assuming a continuing sediment supply at present levels, we have identified the flood requirements of the delta marshes that would be formed by the diversion of the Colorado River into Matagorda Bay.

There is more marsh nutrient export from tidal action than from the less frequent river flooding (Espey, Huston and Associates 1982). However, not all parts of the Lavaca delta are subject to regular tidal inundation. The areas around Redfish Lake and upstream of the confluence of the Lavaca and Navidad Rivers (Fig. 1) are flooded mainly by high river flows (TDWR 1980). These flows provide the bay with both allochthonous materials from upland and floodplain sources and marsh production from these areas not regularly flooded by tides. Espey, Huston and Associates (1977) estimated an annual plant biomass export of at least 6815 tons from the Redfish Lake area. The primary mechanism for export of this material to the estuary is large floods. A flow of approximately 1019 m^3/sec would flood the Redfish Lake area with enough water to facilitate detrital and nutrient export. Floods of this size occur approximately once every 2.8 years, in the months of April, June, and September.

These large floods, which expose the bay to non-tidal detrital and nutrient sources, were related to commercial brown and white shrimp harvests. Early floods (April and June) could influence the current year's catch, but because of food chain delays and the fact that most of year's catch has already passed by September, late floods would have a greater influence on the next year's catch. We postulated that when an early flood occurred, that year's harvest should be larger than both the previous and following year's, and when there was a late flood, the next year's catch would be larger than the current year's. This pattern was followed in six of seven cases for white shrimp and in five of seven cases for brown shrimp (Fig. 3). So while the nutrient budget indicates that river flooding of marshes provides less than 3% of the total Matagorda Bay nutrients (Espey, Huston and Associates 1982), there still appears to be a relationship to productivity for floods large enough to provide the bay with a pulse of detritus and nutrients from sources not regularly available.

TDWR (1980) recommends two floods in the Lavaca delta for the April to June period with a peak discharge of 320 m^3/sec. This is very similar to our recommendation of two 255 m^3/sec average daily flow floods in March, April, May, or June (Table 4). Fall flooding recommendations are also similar. TDWR recommends one 293 m^3/sec peak discharge flood for October to January; we recommend one 255 m^3/sec average daily flow for September and October. We also recommend another 255 m^3/sec average daily discharge event for the November to February period, for a total of four annual "small" floods vs three recommended by TDWR. TDWR made no provisions for large floods or for Colorado River floods.

Conclusion

Our inflow recommendations were derived using fishery dependent data, which may not always accurately reflect productivity. Fishery independent abundance data would provide a better definition of the role of freshwater inflow in maintaining shrimp populations. The Texas Parks and Wildlife Department has a current data collection program that could provide this fishery independent information if it is continued and expanded in future years.

Current reservoir proposals on the Lavaca and Colorado Rivers have the potential to greatly reduce freshwater inflows to the Matagorda Bay System. These reductions, if great enough, would adversely affect the productivity of both the estuary and the adjacent Gulf of Mexico. It is necessary to reiterate the importance of large floods to an estuary such as the Matagorda Bay System. These floods bring large amounts of sediments, nutrients, and detritus from bordering marshes into the bays where they fertilize an important food chain which supports shrimp, crabs, and fish. The biological, economic, and social impacts of freshwater inflow reduction make wise water management decisions critical to the continued prosperity of the Texas coast.

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